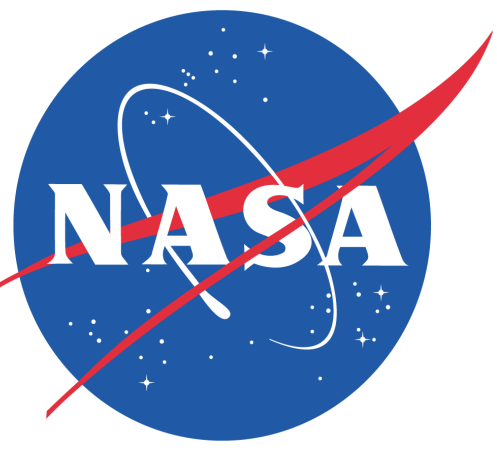# Enhancing USDA's Retrospective Analog Year Analyses Using NASA Satellite Precipitation and Soil Moisture Data

NASA/Goddard EARTH SCIENCES DATA and INFORMATION SERVICES CENTER (GES DISC)

Crop yield estimates derived from satellite data are closer to measured yields than are estimates derived from ground station data.

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Abstract

The **USDA World Agricultural Outlook Board (WAOB)** is responsible for monitoring weather and climate impacts on domestic and foreign crop development. One of WAOB's primary goals is to determine the net cumulative effect of weather and climate anomalies on final crop yields, based on a broad array of information. The resulting agricultural weather assessments are published in the **Weekly Weather and Crop Bulletin.** Because both the **amount and timing of precipitation** significantly affect crop yields, WAOB has often, as part of its operational process, used historical time series of surface-based precipitation observations to visually identify growing seasons with similar (analog) weather patterns as, and help estimate crop yields for, the current growing season.

As part of a larger effort to improve WAOB estimates by integrating NASA remote sensing observations and research results into WAOB's decision-making environment, a more rigorous, statistical method for identifying analog years was developed, termed **analog index (AI)** and based on the Nash–Sutcliffe model efficiency coefficient. The AI was computed for five study areas and six growing seasons of data analyzed (2003-2007 as potential analog years and 2008 as the target year). Previous results have shown that, for all five areas, crop yield estimates derived from satellite-retrieved precipitation data are closer to measured yields than are estimates derived from surface-based precipitation observations (Teng and Shannon, 2011). Subsequent work has shown similar results for satellite-retrieved surface soil moisture data and from root zone soil moisture derived from the assimilation of surface soil moisture data into a land surface model. Establishing the analog methodology in station-rich areas can potentially enable WAOB to apply similar methodology in station-poor areas of the world, thus **significantly extend its global coverage**. WAOB is the focal point for economic intelligence within USDA. Improving WAOB's agricultural estimates will be significant for USDA and visibly demonstrate value of NASA resources for societal benefits.

Analog Year Comparisons

An example …

… between a given year and historical years with similar weather patterns, from New South Wales, Australia.

2006 is the target year…   … 2002 is an analog year.
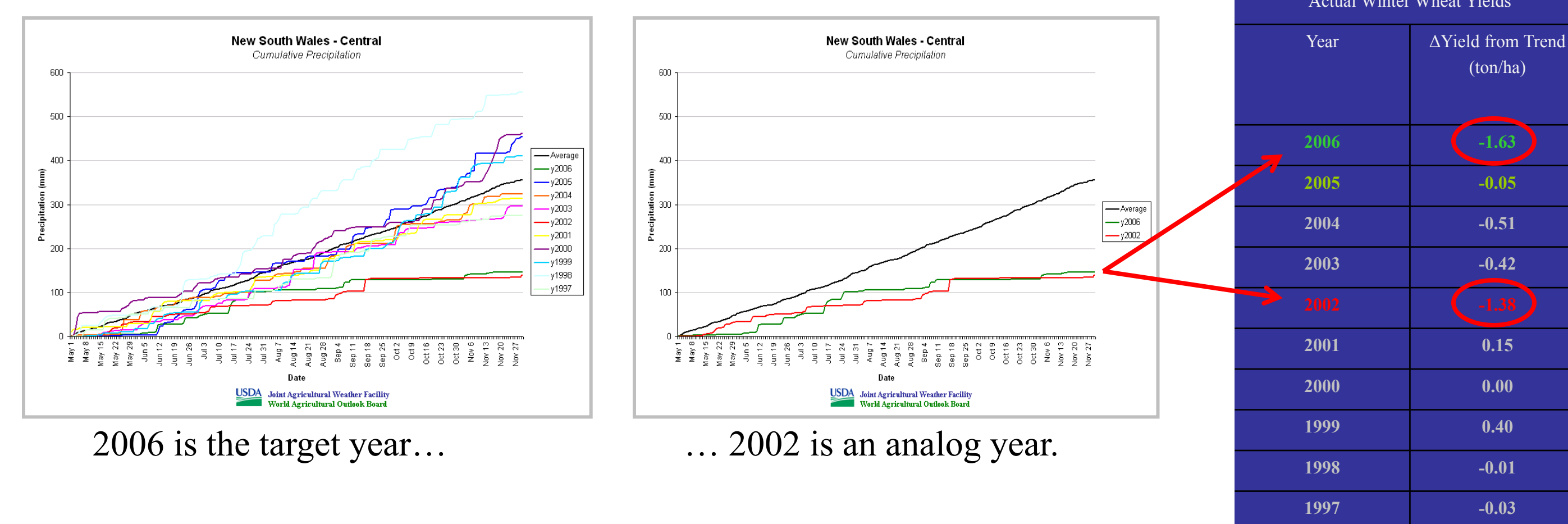
Importance of timing of precipitation relative to stages of crop development. **Timely rainfall** in Western Australia helped elevate 2006 winter wheat yields (1.27 t/ha) to above 2002 levels (0.91 t/ha).
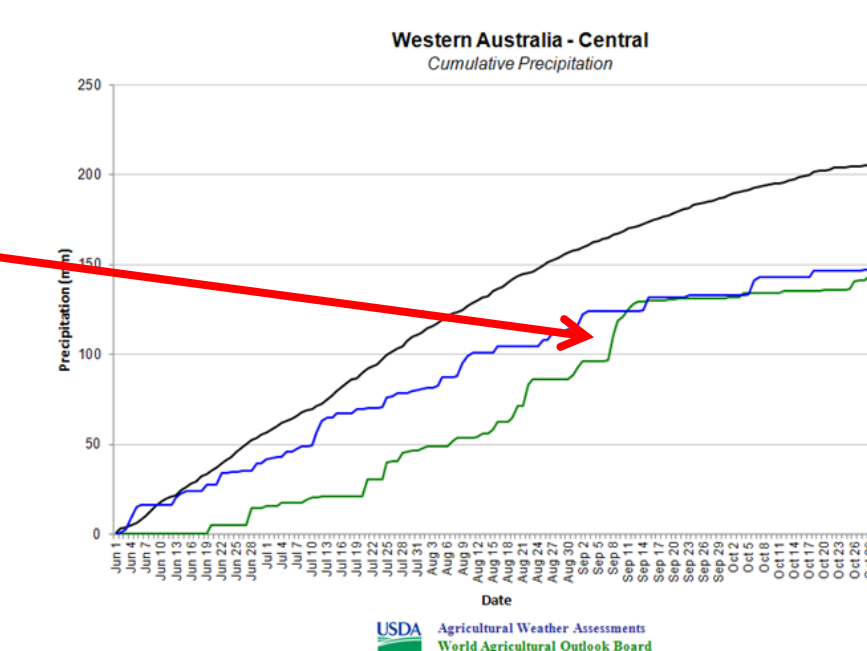
Data Sets

- **Station-based precipitation:** Regional time series derived by averaging daily cumulative precipitation from multiple surface observing stations distributed evenly throughout each study area. **Iowa, U.S.,** 8 stations from NOAA/NWS Cooperative Observer Program (COOP) network; **Jalisco, Mexico,** 4 stations from World Meteorological Organization (WMO) network; **Parana, Brazil,** 6 WMO stations; **central Argentina,** 5 WMO stations; **Free State, South Africa,** 5 WMO stations.

- **Crop yield:** **U.S.,** annual state-level corn statistics from USDA National Agricultural Statistics Service (NASS); **Mexico,** Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA); **Brazil,** annual soybean statistics from Instituto Brasileiro de Geografia e Estatística; **Argentina,** Ministerio de Agricultura, Ganadería y Pesca (MAGyP); **South Africa,** National Estimates Committee (NEC).

- **TRMM Multi-satellite Precipitation Analysis** (TMPA, 3B42) (Huffman et al., 2007): 0.25-deg; daily (averaged from 3-hourly); source data sets merged (TRMM, AMSR-E, SSM/I, others); temporal coverage 1998-present.
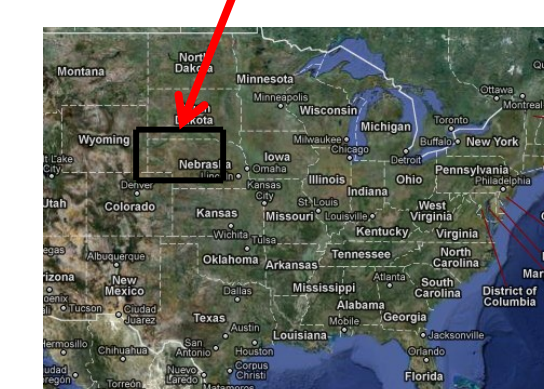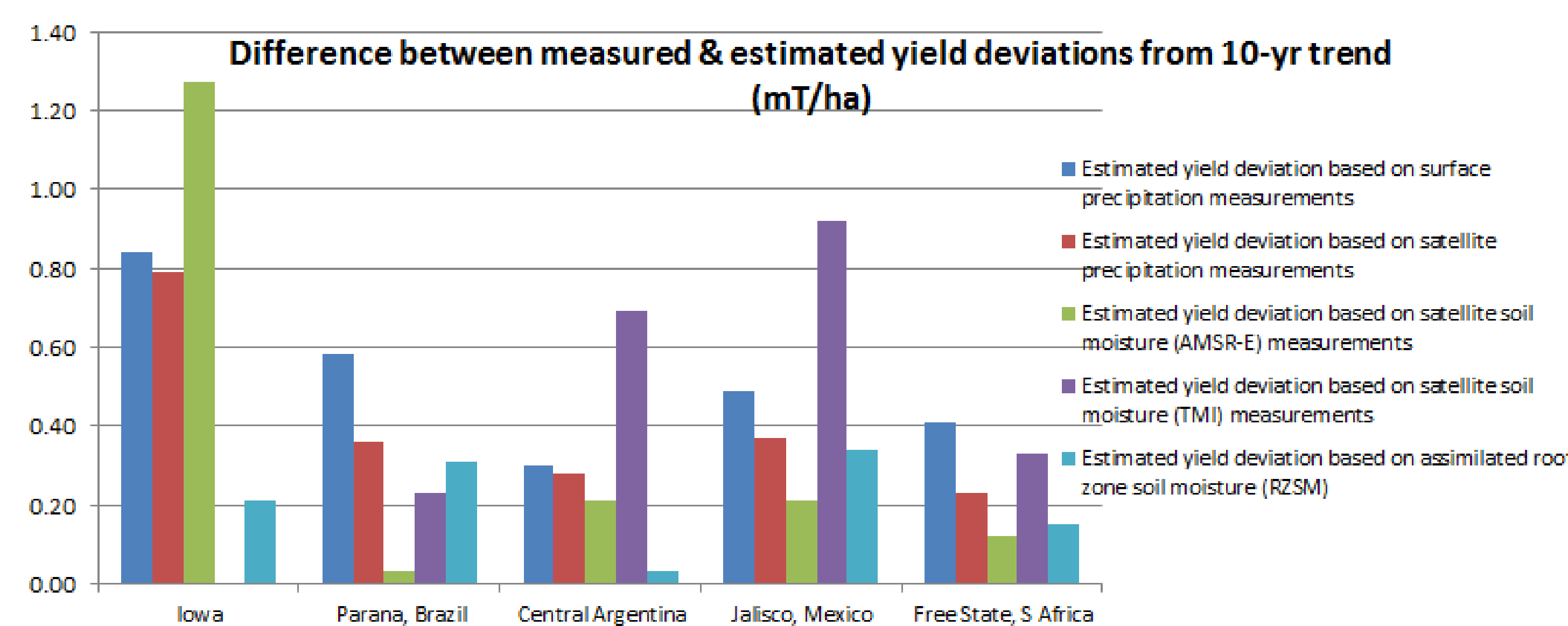
Data Sets (cont.)

(a) 09/30/11   (b) 09/30/11
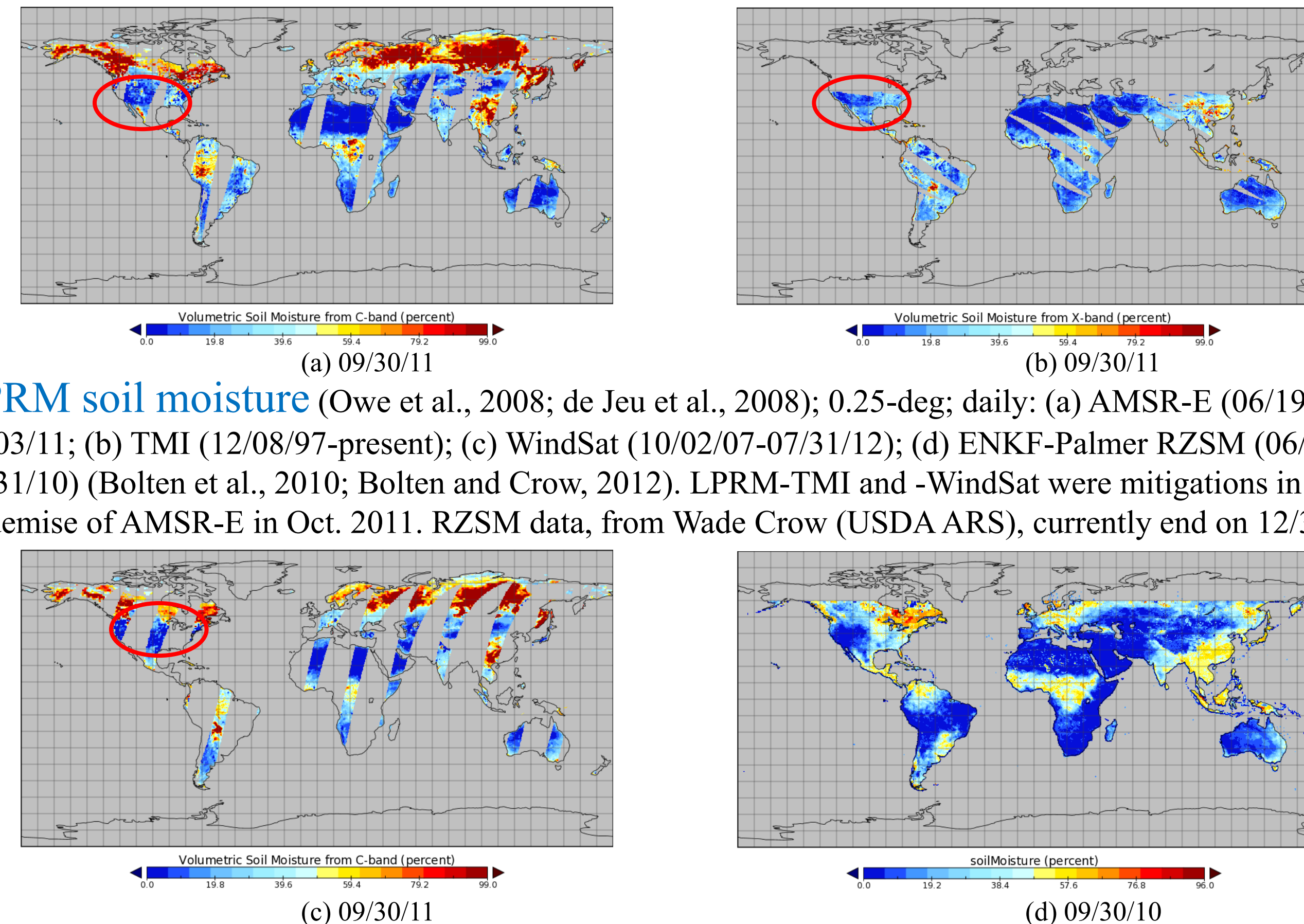
LPRM soil moisture (Owe et al., 2008; de Jeu et al., 2008); 0.25-deg; daily: (a) AMSR-E (06/19/02-10/03/11; (b) TMI (12/08/97-present); (c) WindSat (10/02/07-07/31/12); (d) ENKF-Palmer RZSM (06/20/02-12/31/10) (Bolten et al., 2010; Bolten and Crow, 2012). LPRM-TMI and -WindSat were mitigations in response to demise of AMSR-E in Oct. 2011. RZSM data, from Wade Crow (USDA ARS), currently end on 12/31/10.


(c) 09/30/11   (d) 09/30/10
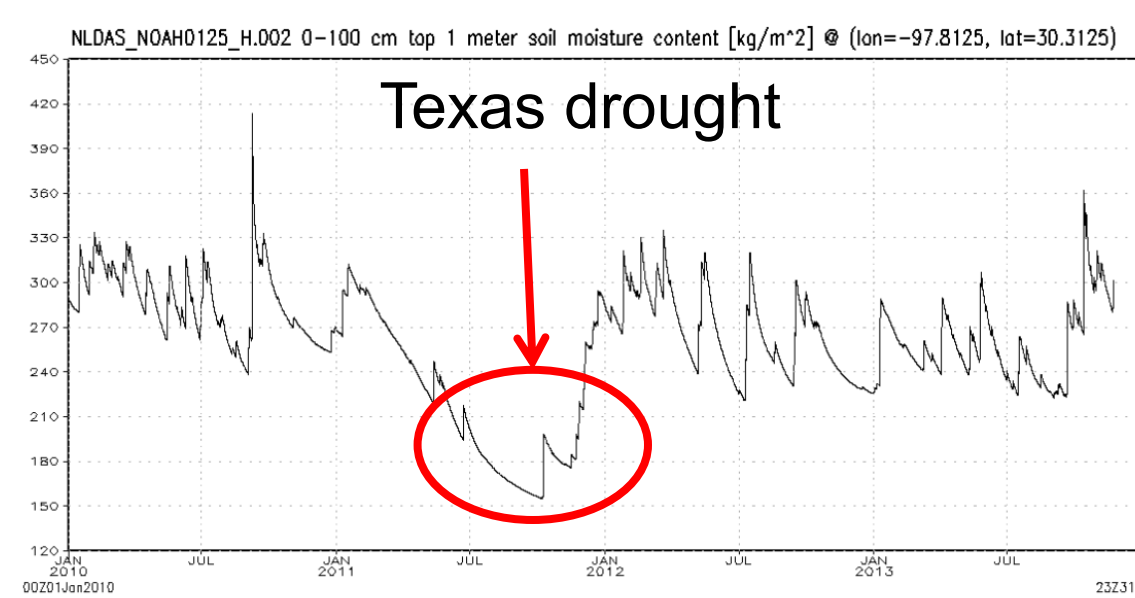
Texas drought

2011 drought in Texas shown by NLDAS (North American Land Data Assimilation System) Noah 0-100 cm soil moisture content. (See soil moisture maps (a)-(c) above.)

Results

Difference between measured & estimated yield deviations from 10-yr trend (mT/ha)

- Estimated yield deviation based on surface precipitation measurements
- Estimated yield deviation based on satellite precipitation measurements
- Estimated yield deviation based on satellite soil moisture (AMSR-E) measurements
- Estimated yield deviation based on satellite soil moisture (TMI) measurements
- Estimated yield deviation based on assimilated root zone soil moisture (RZSM)

Iowa: Largest corn producing state in U.S. (~19% of domestic production). U.S. is world's largest corn producer and exporter.
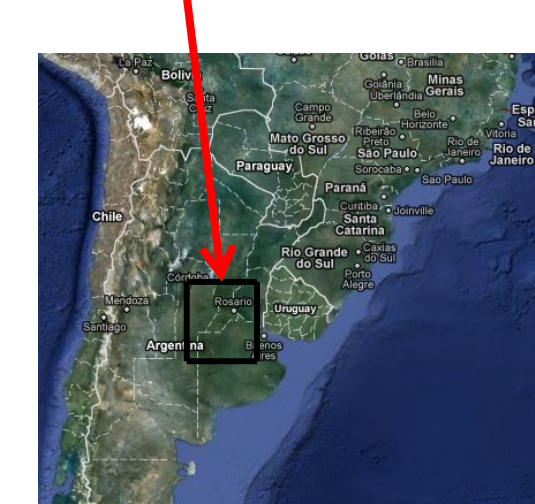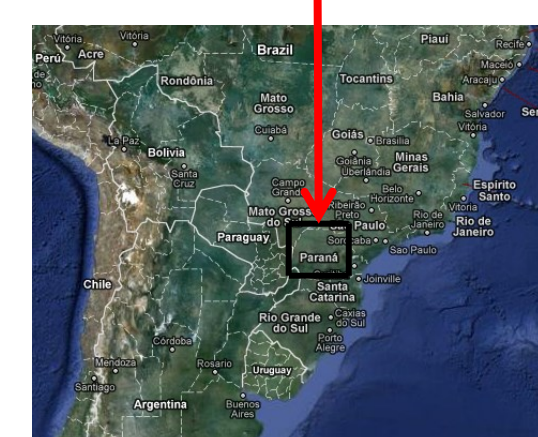
Argentina: World's 2nd largest exporter, and 5th largest producer, of corn.
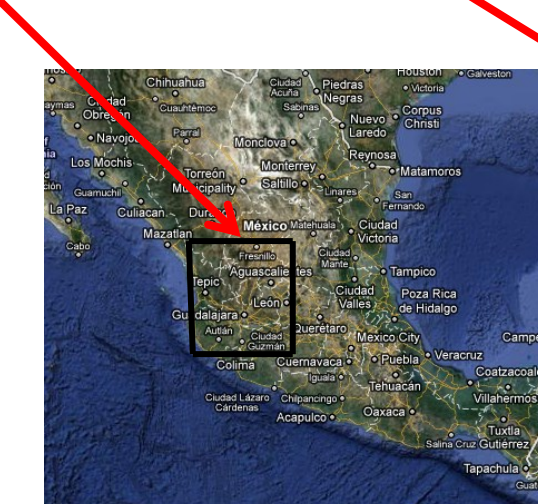
~70% total corn production in Mexico come from 8 states, including Jalisco. Mexico is 4th largest corn producing country in the world.

Free State: Largest corn-producing state in South Africa.

Parana: One of the largest soybean-producing states in Brazil (a major soybean exporter).

Five major agricultural regions worldwide were analyzed. The size of individual study areas selected depends on the variability of weather within each area and the availability of crop yield data.

Results (cont.)

REGION (crop)	Measured yield deviation from the 10-yr trend (mT/ha)	Estimated yield deviation based on OBS-SFC	Absolute value of OBS-SFC	Estimated yield deviation based on SAT data	Absolute value of OBS-SAT	Absolute value of OBS-TMPA	Estimated yield deviation based on AMSRE	Absolute value of AMSRE	Estimated yield deviation based on TMI data	Absolute value of OBS-TMI	Estimated yield deviation based on RZSM data	Absolute value of OBS-RZSM
Iowa, U.S.A. (corn)	-0.53 (mT/ha)	0.31	**0.84**	0.26	**0.79**	0.74	**1.27**	N/A		-0.32	**0.21**	
Parana, Brazil (soybean)	0.33 (mT/ha)	-0.24	**0.58**	-0.03	0.36	0.30	0.03	0.10	**0.23**	0.03	**0.31**	
central Argentina (corn)	-0.79 (mT/ha)	-0.49	**0.30**	-0.51	0.28	-0.57	**0.21**	-0.10	**0.69**	-0.75	**0.03**	
Jalisco, Mexico (corn)	-0.44 (mT/ha)	0.05	**0.49**	0.37	0.37	0.21	**0.21**	0.14	**0.92**	-0.10	**0.34**	
Free State, South Africa (corn)	0.53 (mT/ha)	0.13	**0.41**	0.30	0.23	0.41	0.12	0.20	**0.33**	0.38	**0.15**	

- For all five study areas, **OBS-SFC > OBS-SAT (TMPA) > OBS-RZSM**
- Except for Iowa, OBS-SFC > OBS-AMSRE
- Results for TMI mixed (data gaps, X-band only)
- Traditional, visual method of identifying analog years also improved with addition of satellite data. WAOB agricultural meteorologist, provided with same data that this study used, also selected analog year(s) with better yield estimates, for all study areas.

- Crop yield estimates derived from satellite-based precipitation and soil moisture data are closer to measured yields than are estimates derived from surface-based precipitation measurements.
- Establishing analog analysis methodology in station-rich areas and apply in station-poor areas of the world potentially can significantly extend WAOB's global coverage.
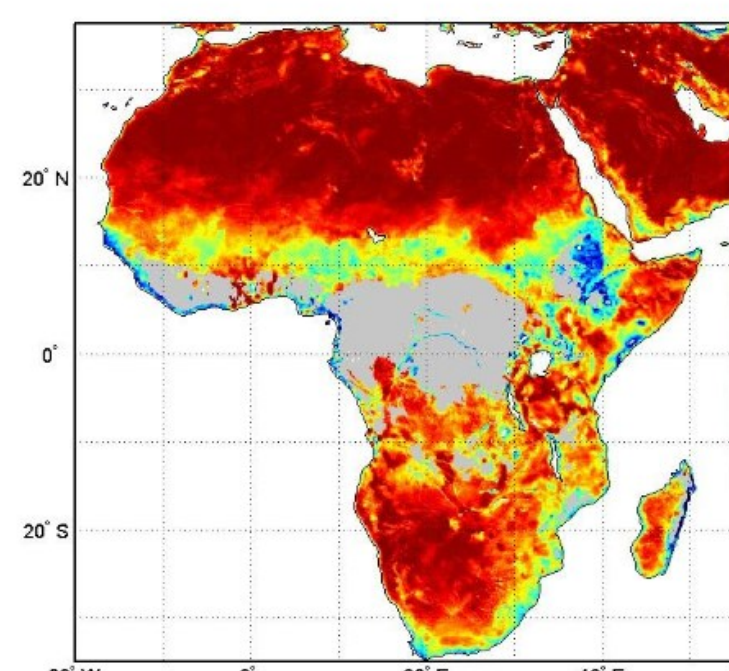
Integration into WAOB Operational Environment

Giovanni … Quick access to soil moisture and related data

Check it out!

Soil moisture (m3/m3) from AMSR-2 for August 2013
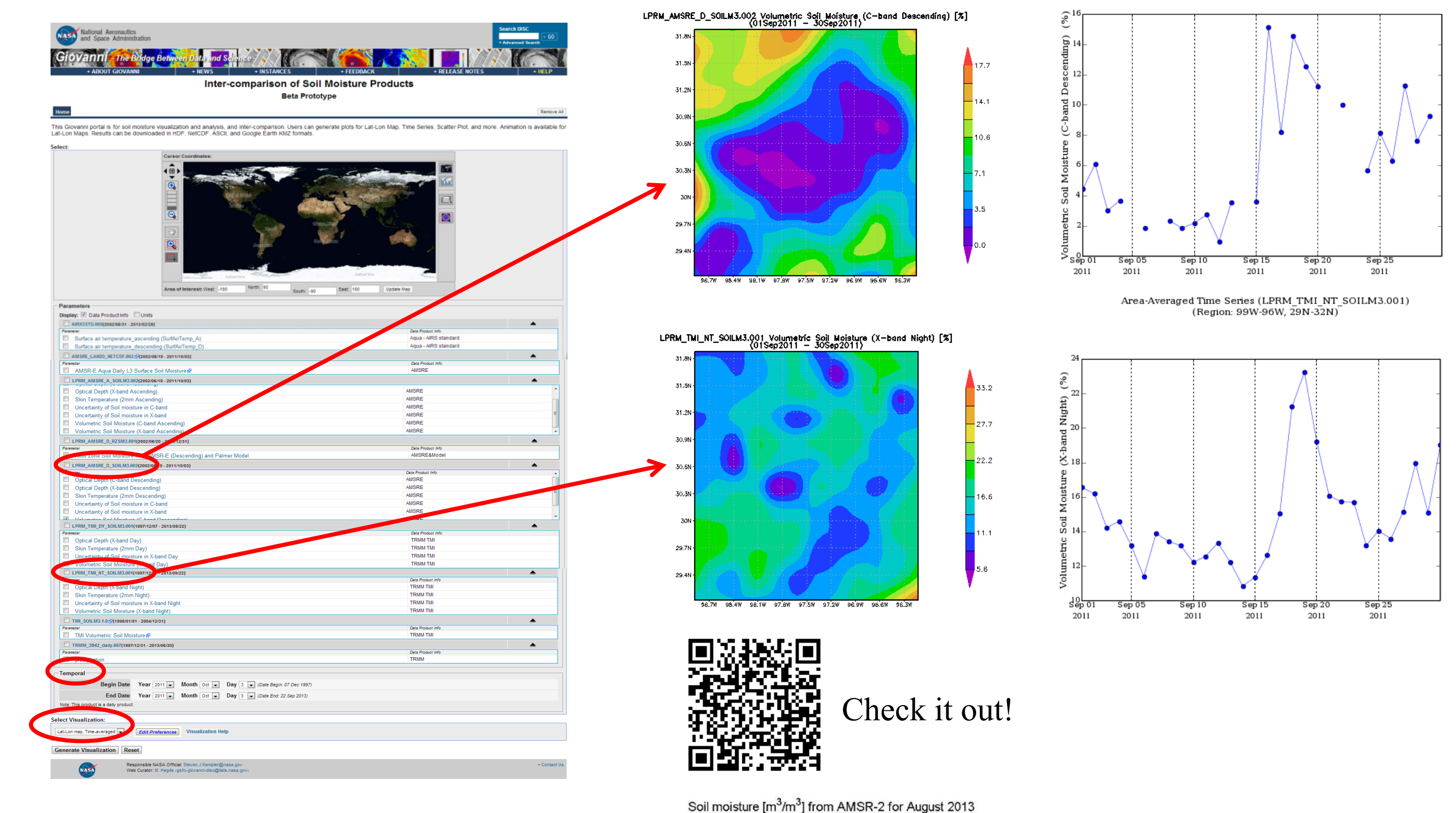
Importance of forward-processed data stream …

- Extend WindSat coverage and possibly establish forward data stream.
- Establish forward RZSM data stream.
- Apply LPRM to AMSR2 on JAXA's GCOM-W1.

Sample soil moisture map from LPRM-AMSR2 (courtesy of Robert Parinussa, Vrije Universiteit-Amsterdam, VUA)

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Acknowledgment